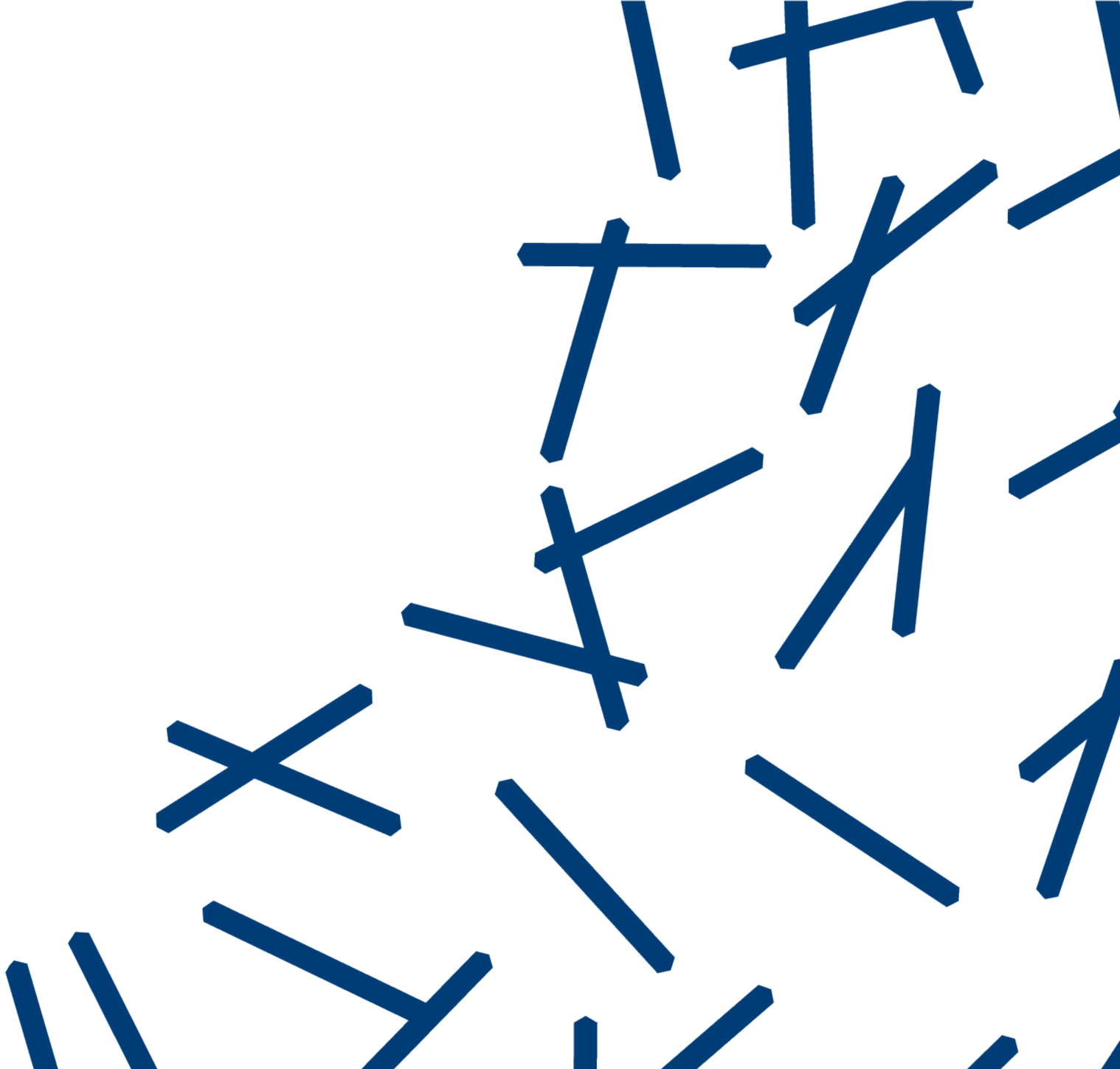
Yale ENGINEERING

Non-determinism

Rajit Manohar



AVLSI

Non-deterministic selection

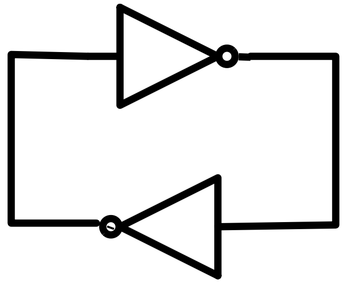
```
*[  [| #A -> A?x
    [] #B -> B?x
    |];
    Z!x
 ]
```

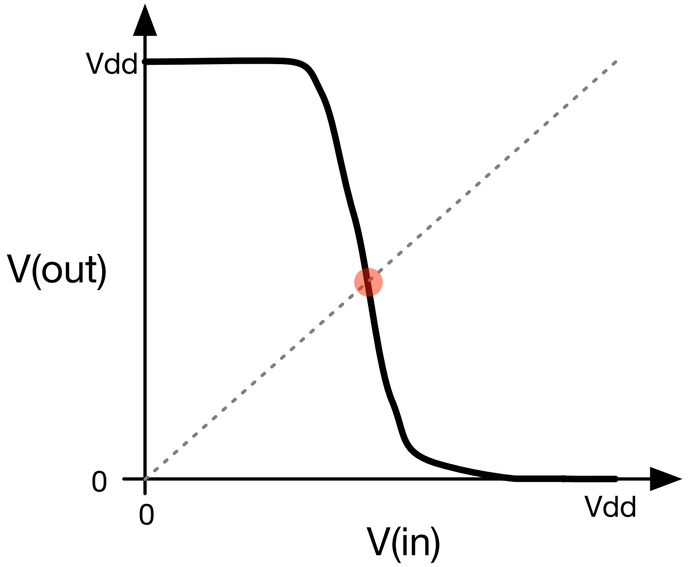
- When a communication is pending on both A and B
  - ❖ We can pick either
    … but we have to make a choice
  - ❖ The **arbitration** problem

> Should two courses be judged equal, then the will cannot break the deadlock, all it can do is to suspend judgement until the circumstances change, and the right course of action is clear.
>
> — Jean Buridan, c. 1340

Metastable state

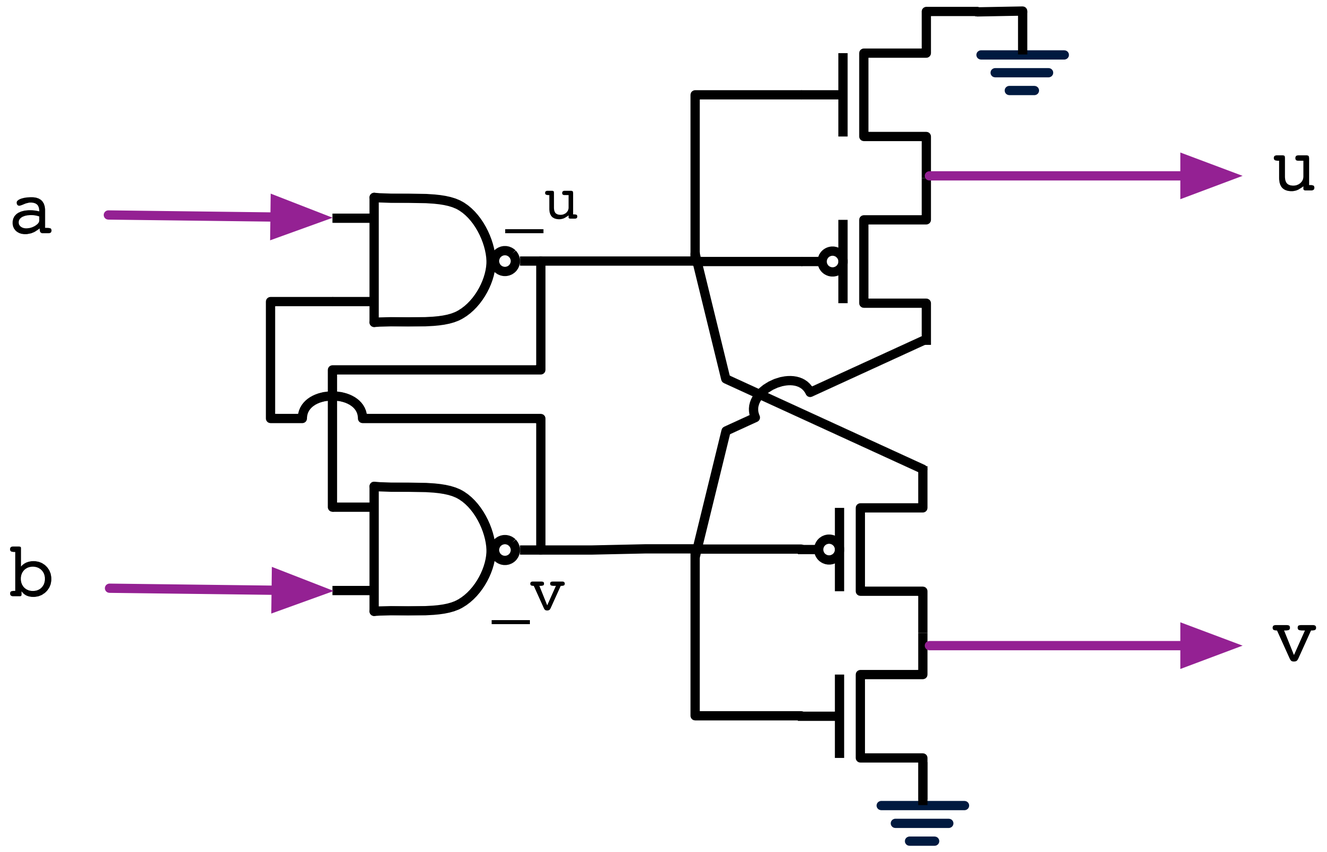
- Unstable equilibrium
  - Inverted pendulum
  - Balancing a pencil on its tip



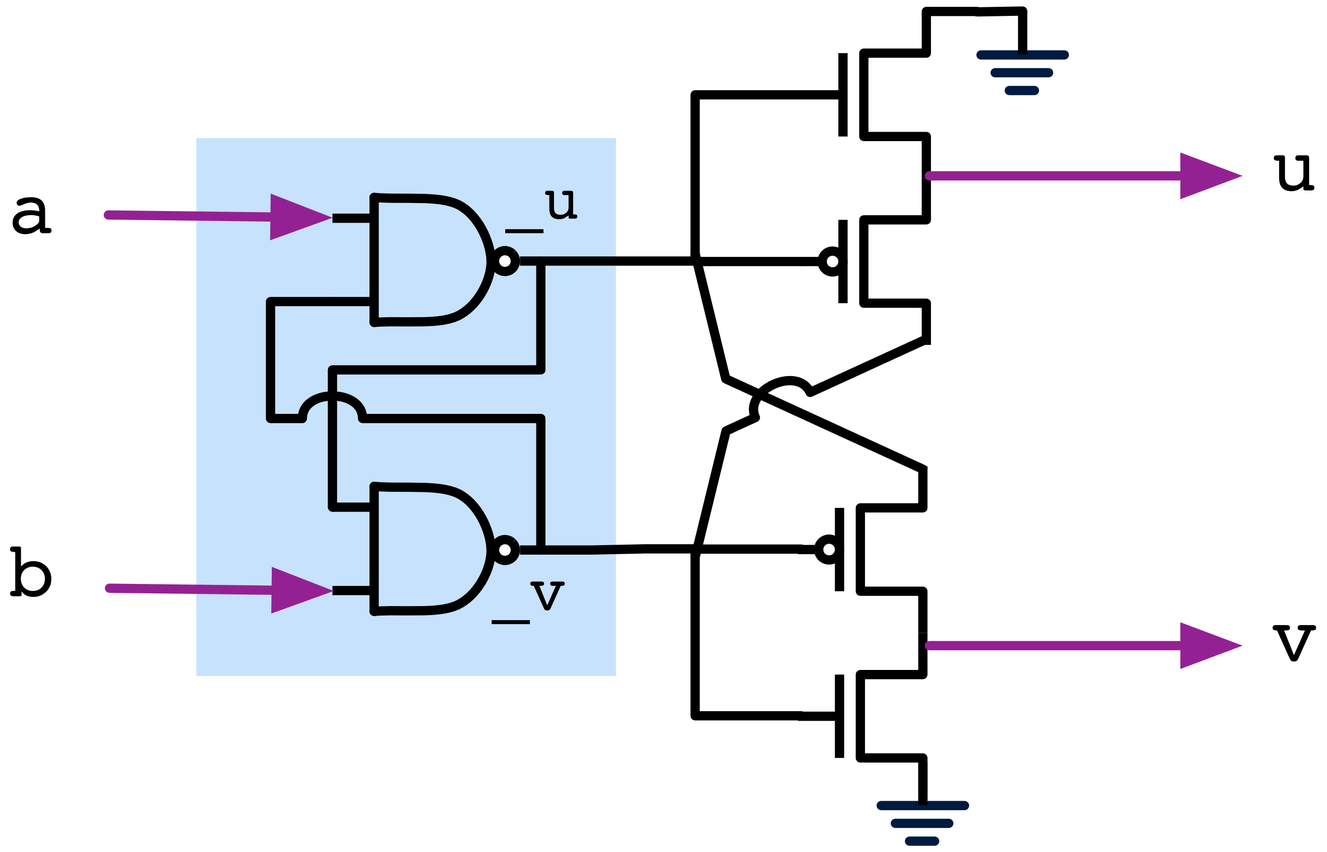


- Another example: cross-coupled inverter
  - Stable states: 0/1 and 1/0
  - Metastable state: V(out) = V(in)

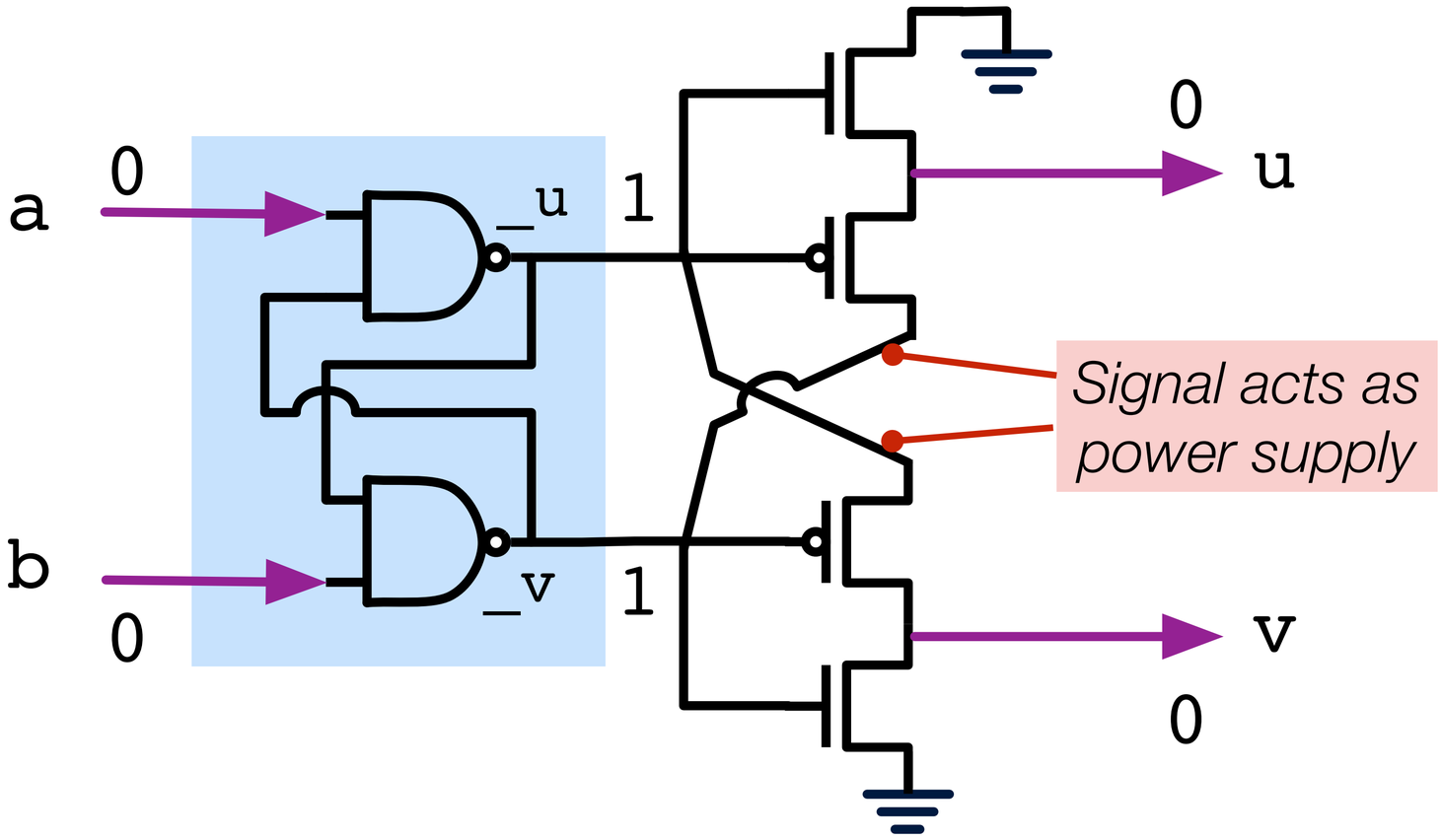
Arbiter



Arbiter



Arbiter



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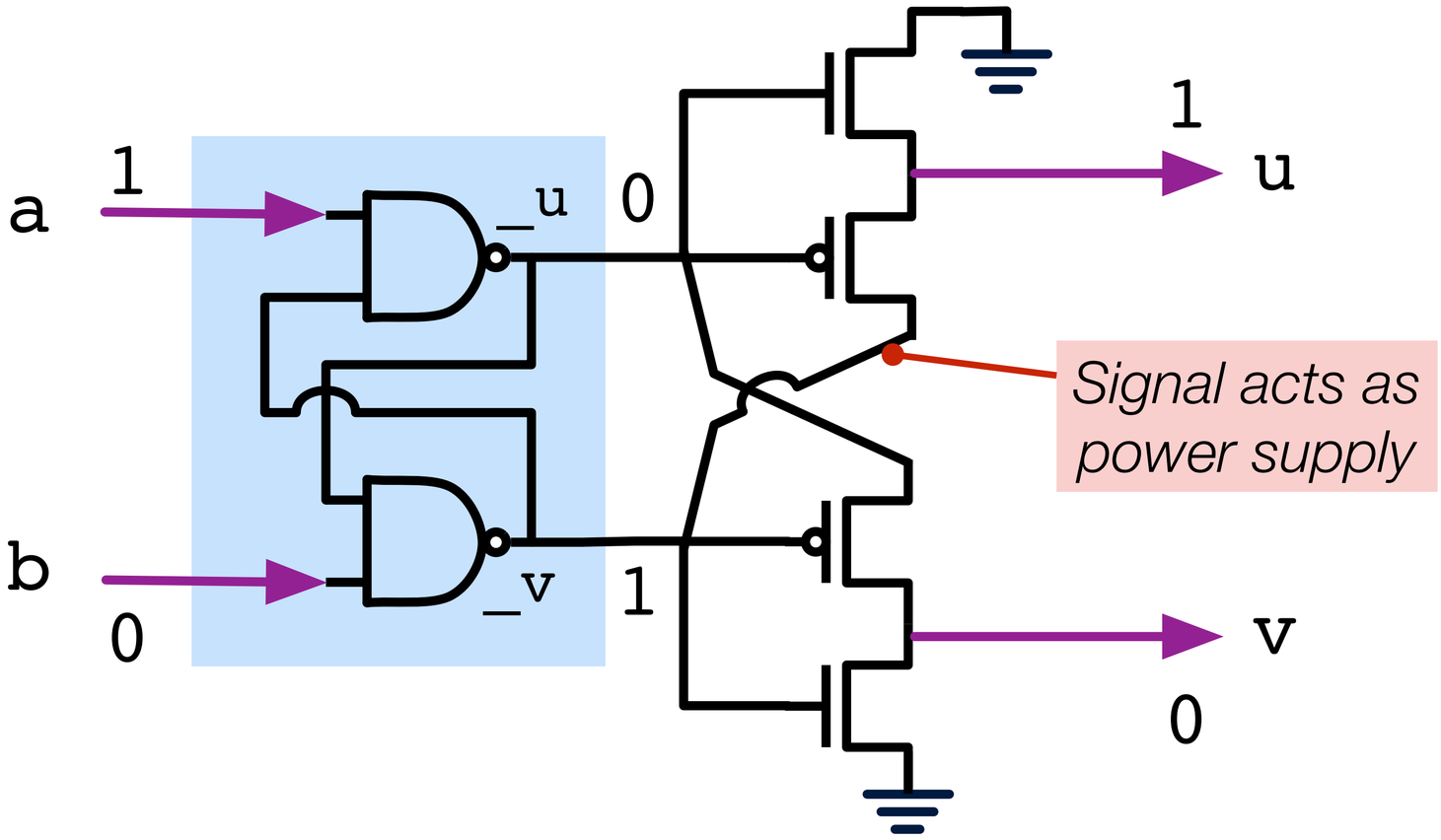
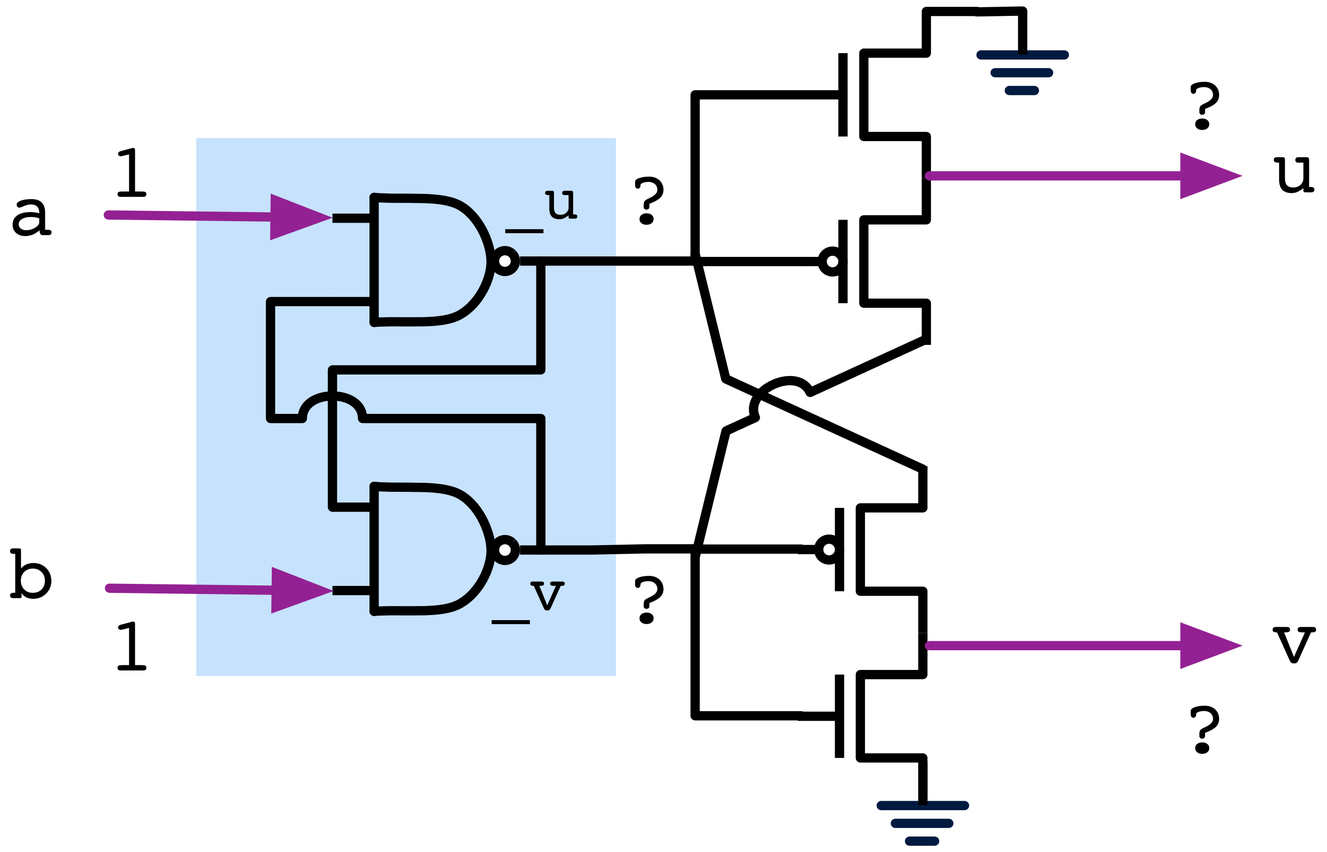
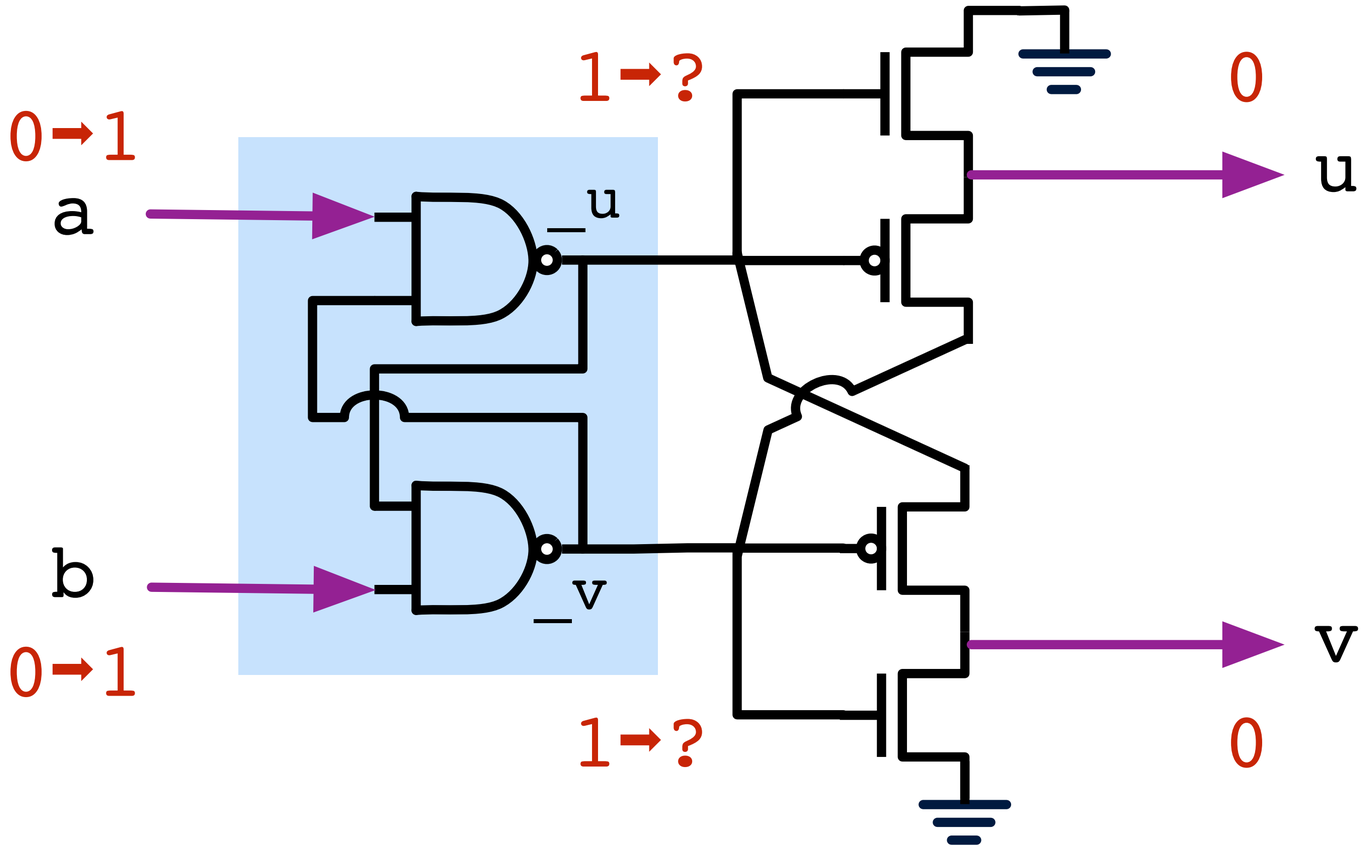


Arbiter



$$\Pr[\text{time} \geq t] = Ae^{-t/\tau}$$

Arbiter



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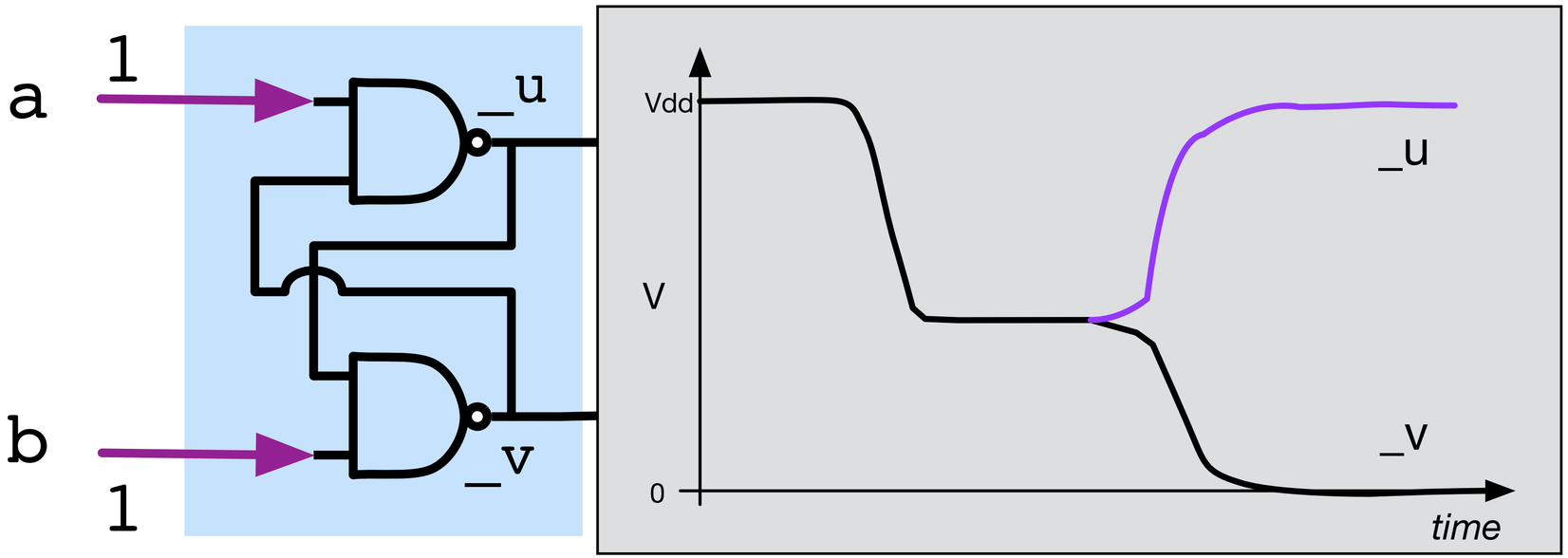
Arbiter



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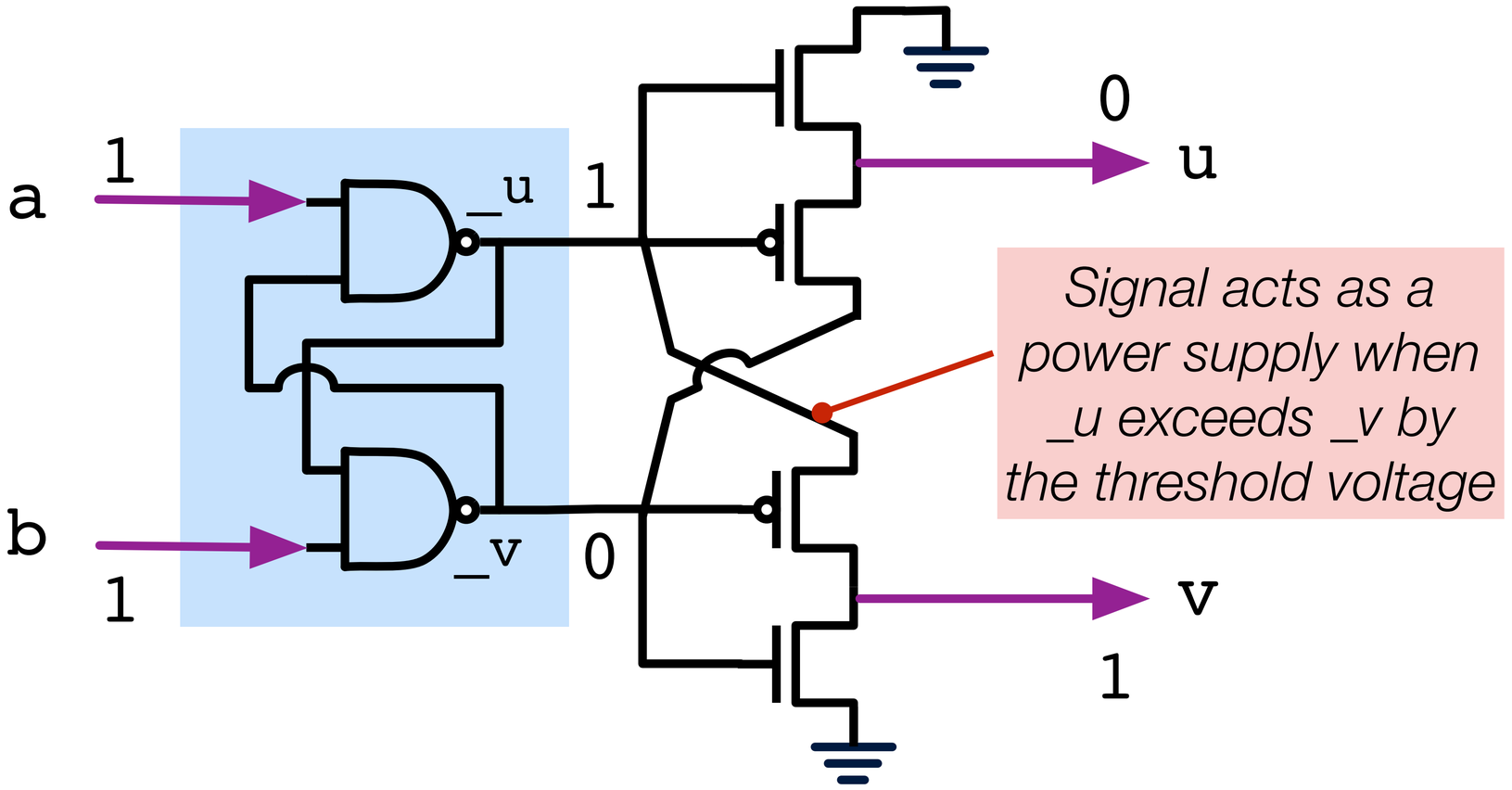
Arbiter

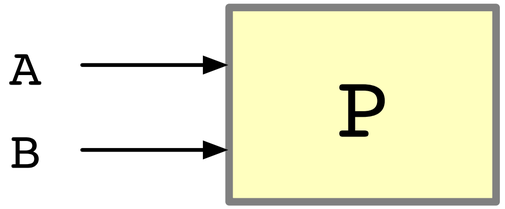


$$\Pr[\text{time} \geq t] = Ae^{-t/\tau}$$

Translating non-deterministic selections

- Basic idea

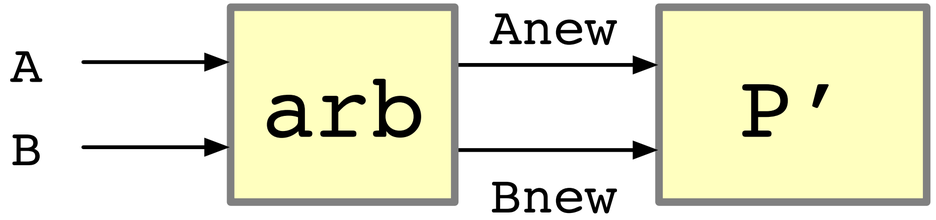
```
[| #A -> A?x
[] #B -> B?x
|]
```



❖ Factor out non-deterministic execution

```
*[
  [| #A -> Anew!A;A?
  [] #B -> Bnew!B;B?
  |]
 ]
```

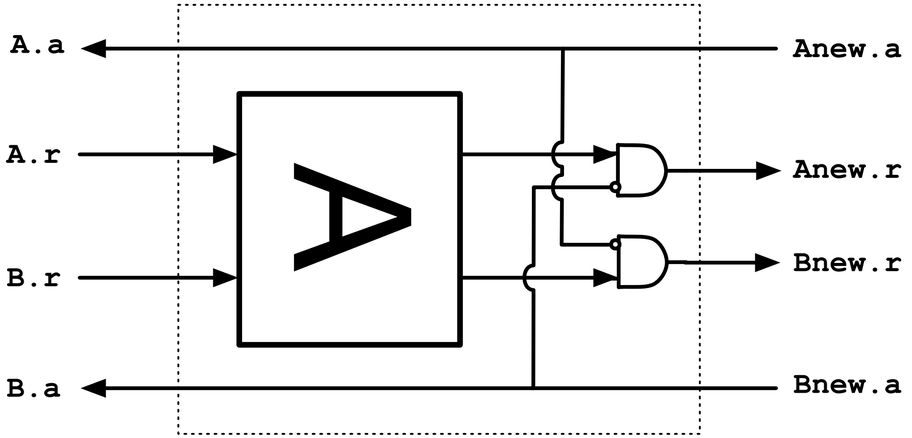
```
[ #Anew -> Anew?x
[] #Bnew -> Bnew?x
]
```



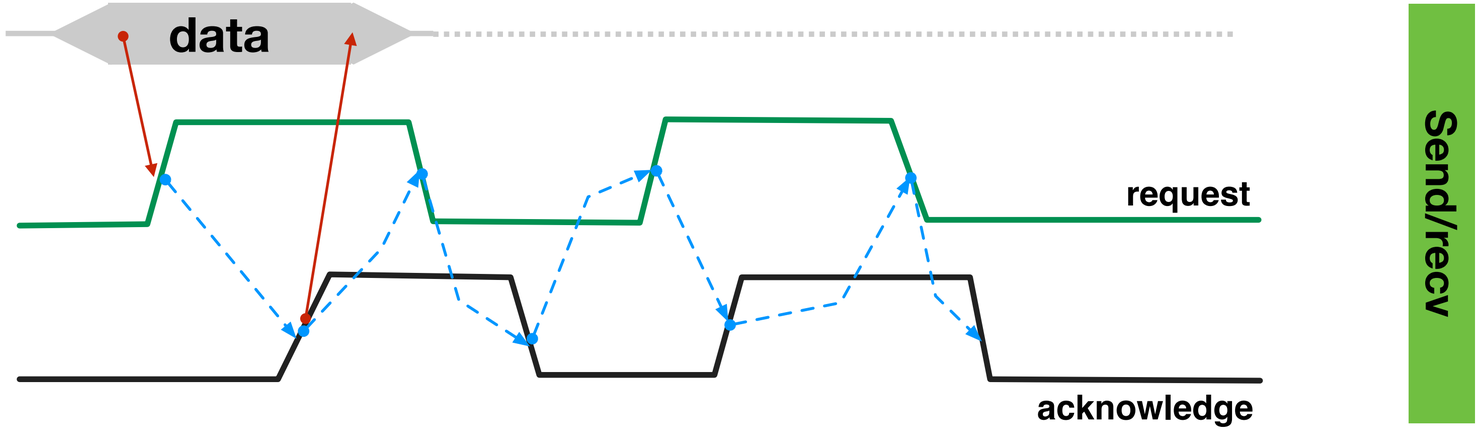
standard component

Example circuit

```
*[
  [| #A -> Anew!A;A?
  [] #B -> Bnew!B;B?
  |]
 ]
```

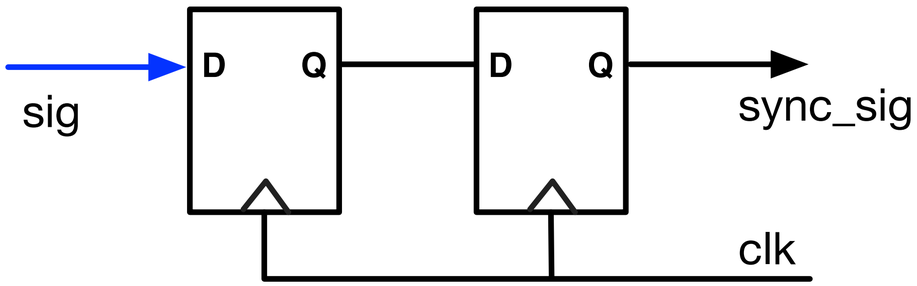


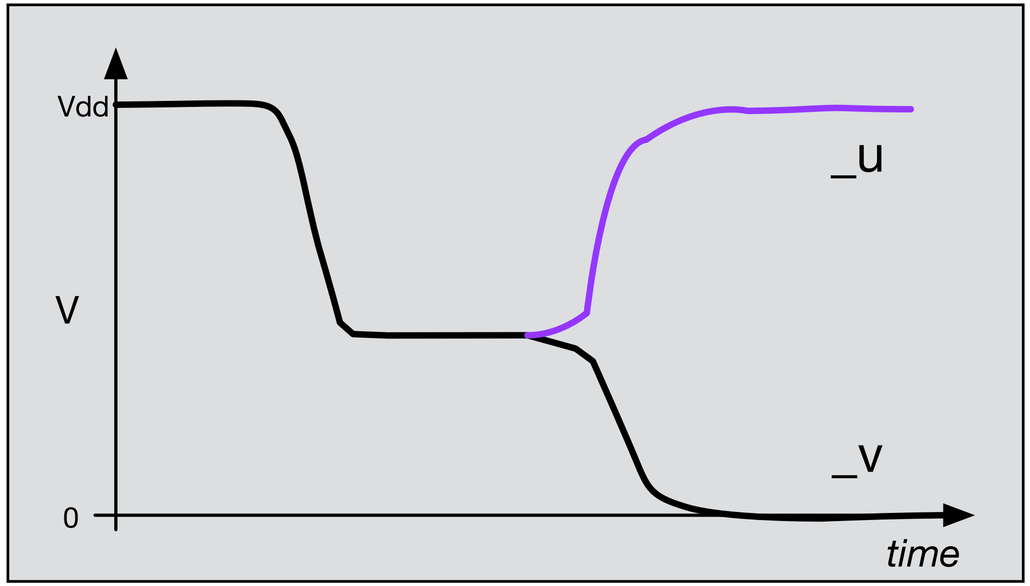
A simple (slow) interface to clocked environments



- Send to clocked environment
  - Request might change when the clock is changing
- Receive from clocked environment
  - Acknowledge might change when the clock is changing

Standard synchronizer: a sequence of flip-flops





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